

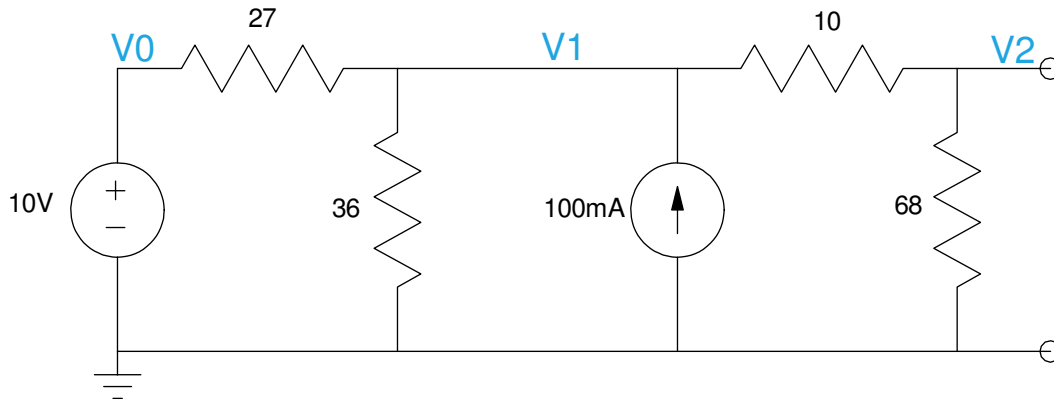
ECE 211 Test #2

Thevenin Equivalents - Max Power Transfer - Superposition - Operational Amplifiers

Thevenin Equivalent

Determine the Thevenin equivalent for the following circuit.

- Please show your work to get full credit



There are several ways to do this.

V_{th}: Find the open-circuit voltage (V_{th}). Start with finding the voltage at V₁ by writing the voltage node equation at V₁

$$\left(\frac{V_1 - 10}{27}\right) + \left(\frac{V_1}{36}\right) - 100mA + \left(\frac{V_1}{68}\right) = 0$$

$$V_1 = 6.0587V$$

By voltage division

$$V_2 = \left(\frac{68}{68+10}\right) V_1 = 5.2820V$$

$$\mathbf{V_{th} = 5.2920V}$$

R_{th}: Turn off the sources and find the resistance looking in

$$>> R1 = 1 / (1/27 + 1/36)$$

$$R1 = 15.4286$$

$$>> R2 = 10 + R1$$

$$R2 = 25.4286$$

$$>> R3 = 1 / (1/68 + 1/R2)$$

$$R3 = 18.5076$$

$$\mathbf{R_{th} = 18.5076\ Ohms}$$

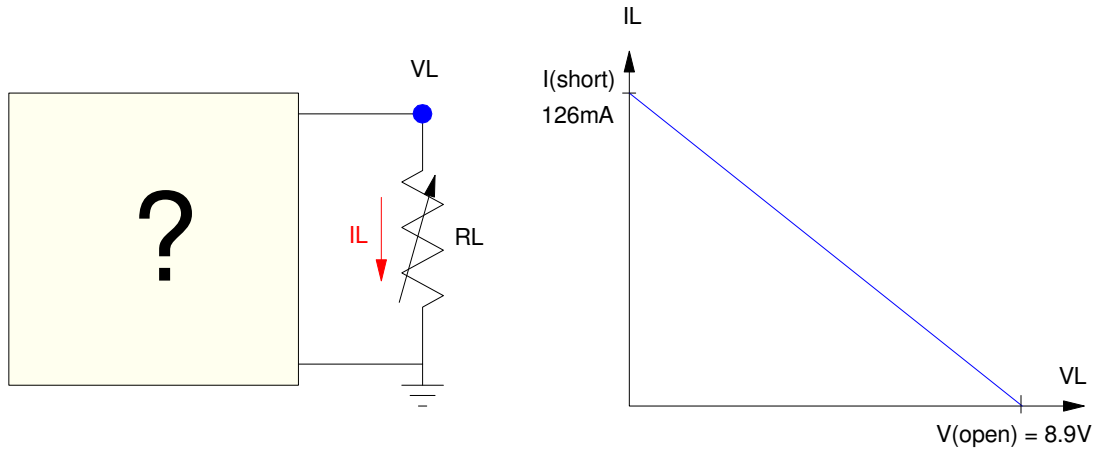
Max Power Transfer

Assume an unknown circuit has the following characteristics:

- Open-circuit voltage = 8.90V ($R_L = \text{infinity}$)
- Short-circuit current = 126mA ($R_L = 0$)

Find

- R_L for the maximum power transfer to the load
- The maximum power you can get from this circuit



Convert to a Thevenin equivalent

$$V_{th} = V_{open} = 8.90\text{V}$$

$$R_{th} = \left(\frac{V_{open}}{I_{short}} \right) = \left(\frac{8.90\text{V}}{126\text{mA}} \right) = 70.6349\Omega$$

Max power transfer is when $R_L = R_{th}$

$$\mathbf{R_L = 70.6349\text{ Ohms}}$$

The power transferred is half of the power from the source (50% efficient)

$$P_{total} = \left(\frac{(8.90\text{V})^2}{70.6349\Omega + 70.6349\Omega} \right) = 560.70\text{mW}$$

$$P_{load} = \frac{1}{2}P_{total} = 280.35\text{mA}$$

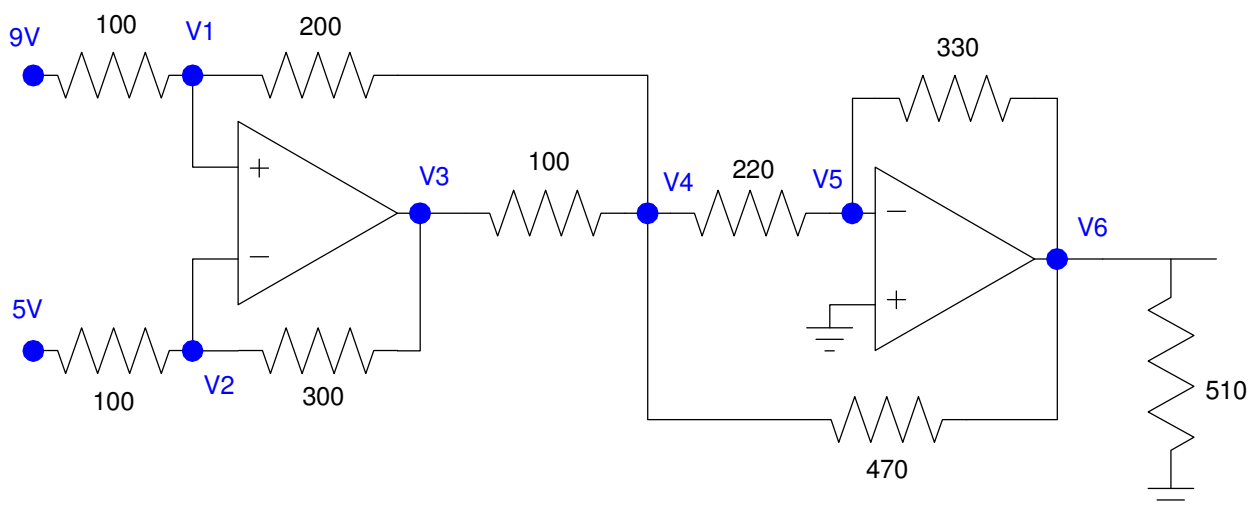
$$\mathbf{P(\text{load}) = 280.35\text{mW}}$$

There are other ways to solve this problem

Ideal Op-Amps

Write the voltage node equations for the following circuit.

- Assume ideal op-amps.
- You don't need to solve (just write six equations for six unknowns)



Start with the easy equations ($V_p = V_m$)

$$V_1 = V_2$$

$$V_5 = 0$$

Now write the node equations

Node V1

$$\left(\frac{V_1 - 9}{100} \right) + \left(\frac{V_1 - V_4}{200} \right) = 0$$

Node V2

$$\left(\frac{V_2 - 5}{100} \right) + \left(\frac{V_2 - V_3}{300} \right) = 0$$

Node V4

$$\left(\frac{V_4 - V_1}{200} \right) + \left(\frac{V_4 - V_3}{100} \right) + \left(\frac{V_4 - V_5}{220} \right) + \left(\frac{V_4 - V_6}{470} \right) = 0$$

Node V5

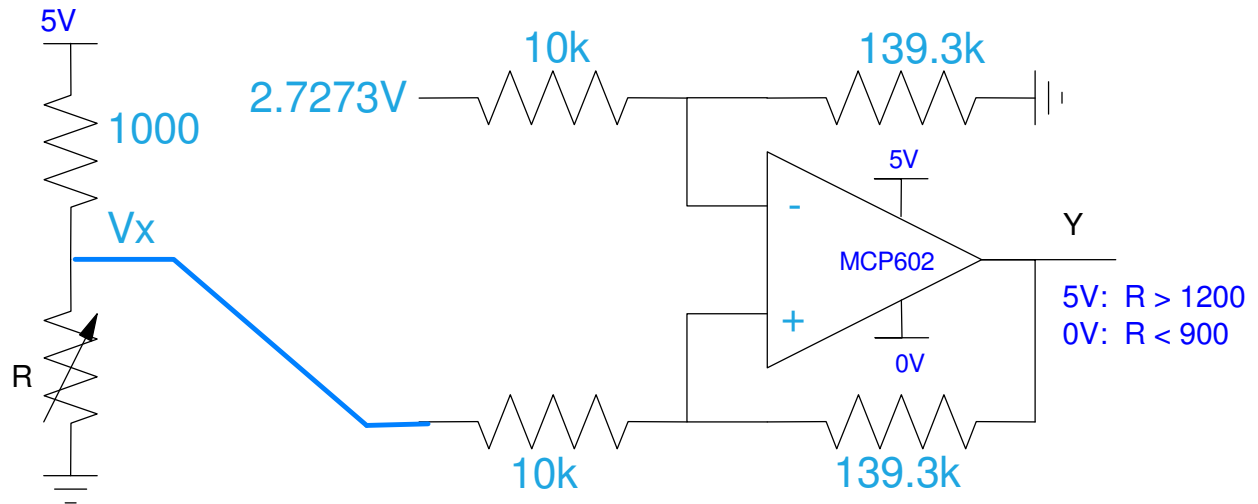
$$\left(\frac{V_5 - V_4}{220} \right) + \left(\frac{V_5 - V_6}{330} \right) = 0$$

note: You can't write the voltage node equation at V3 or V6 (you don't know the current out of the op-amp).

Schmitt Triggers

Design a circuit which outputs

- 5V when $R > 1200$ Ohms
- 0V when $R < 900$ Ohms
- No change for $900 < R < 1200$ Ohms



Assume a 1k resistor (nice round number)

$R = 1200$ Ohms (on)

$$V_x = \left(\frac{1200}{1200+1000} \right) 5V = 2.7273V$$

$R = 900$ Ohms (off)

$$V_x = \left(\frac{900}{900+1000} \right) 5V = 2.3684V$$

$V(\text{on}) > V(\text{off})$

- connect to the plus input

Offset voltage = $V(\text{on})$

Gain

$$\text{gain} = \left(\frac{5V-0V}{2.7273V-2.3684V} \right) = 13.9333$$

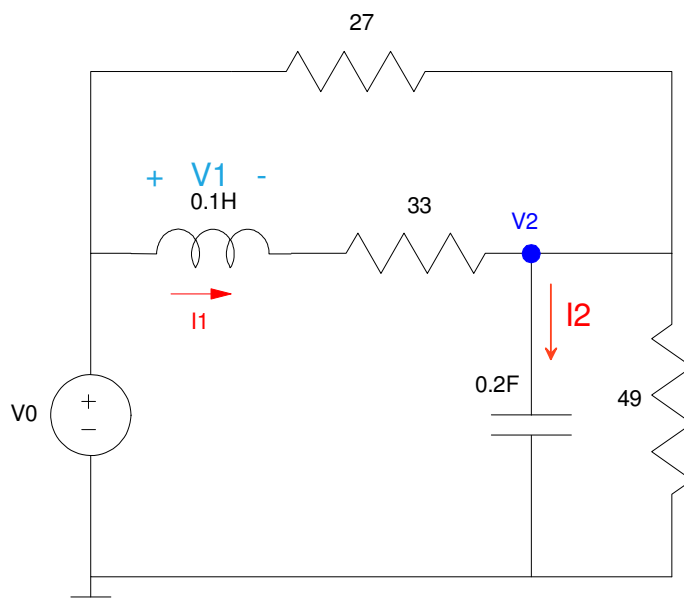
Capacitors & Inductors

Write the differential equations which describe the following RLC circuit

- You don't have to solve - just write the differential equations
- hint: Use the inductor and capacitor VI equations:

$$V = L \frac{dI}{dt}$$

$$I = C \frac{dV}{dt}$$



Inductor

$$V_1 = 0.1 \frac{dI_1}{dt} = V_0 - 33I_1 - V_2$$

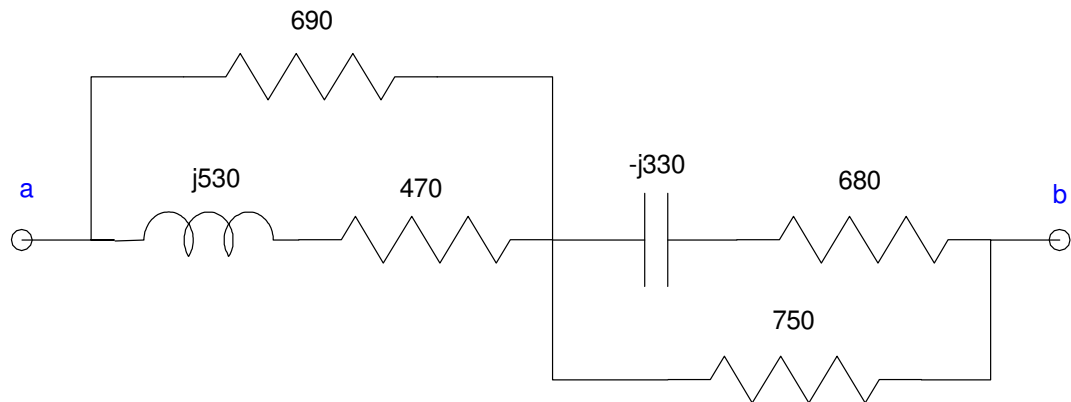
Capacitor

$$I_2 = 0.2 \frac{dV_2}{dt} = I_1 - \left(\frac{V_2 - V_0}{27} \right) - \left(\frac{V_2}{49} \right)$$

Phasors

Find the impedance Z_{ab}

- Please show your work to get full credit



Using Matlab as a calculator

```
>> Z1 = 1 / (1/690 + 1/(470+530j))  
Z1 = 3.5045e+002 +1.5514e+002i  
>> Z2 = 1 / (1/750 + 1/(680-330j))  
Z2 = 3.7653e+002 -8.6185e+001i  
>> Zab = Z1 + Z2  
Zab = 7.2698e+002 +6.8954e+001i  
>>
```

Answer: **$Z_{ab} = 726.98 + 68.954j$**